A Wavelet-based Multi-spectral Codec for Efficient Detection of Cervical Neoplasia from Encoded Cervical Images

Shuyu Yang [1], Jiangling Guo [1], Sunanda Mitra [1], Brian Nutter [1],
Daron Ferris [2], Rodney Long [3]
[1] Texas Tech University
Sunanda.Mitra@coe.ttu.edu
[2] Medical College of Georgia
dferris@mail.mcg.edu
[3] National Library of Medicine
long@lhc.nlm.nih.gov

Abstract

The significance and need for expert interpretation of cervigrams in the study of human papillomavirus (HPV) are currently being investigated. Results of these preliminary studies suggest development and integration of new optical probes for detection and discrimination of cervical neoplasia using automated image analysis tools to reduce subjective variability and to provide remote areas with effective screening tools for early detection of cervical cancer. However, long-term studies using already available cervical images are needed to validate the potential of automated classification and recognition algorithms in discriminating cervical neoplasia and normal tissue. For the effective dissemination of cervical image data over the Web from a central repository to various study groups, it is essential that the image file size be reduced by advanced color data compression techniques while preserving crucial features of color and spatial details. We present the preliminary results of the effectiveness of a novel, wavelet-based, multi-spectral codec in retaining diagnostic features in encoded cervical images.

1. Introduction

Cervical cancer is the second most common cancer affecting women worldwide, and in the United States approximately 15,000 women per year are diagnosed with cervical cancer [1]. According to a recent survey, there are approximately 371,000 cases of cervical cancer diagnosed annually and approximately 190,000 deaths per year on a worldwide basis. Although with appropriate and accurate monitoring, along with proper diagnosis and treatment, cervical cancer can be prevented, women continue to suffer from the consequences of cervical neoplasia because of a relatively insensitive, and frequently non-existent screening test, nonspecific triage assays and subjective colposcopic appraisal. Hence, significant disease commonly remains undetected, and still women may be referred inappropriately for further diagnostic evaluation. Despite the success of the Papanicolaou (Pap) smear in reducing mortality rates, high false positive rates have been reported, thus requiring unnecessary invasive and costly procedures [2].

Proceedings of the 16th IEEE Symposium on Computer-Based Medical Systems (CBMS'03)
1063-7125/03 $17.00 © 2003 **IEEE**

Fluorescence and reflectance spectroscopy [3] may have potential to enhance cervical cytology, colposcopy and histologic analysis and to yield future methods for improved screening and diagnosis of cervical neoplasia. Multi-spectral imaging techniques [4] coupled with advanced discrimination algorithms may also have the potential of improving cervical cancer prevention and thus the possibility of improving healthcare in women and reducing health care costs. These recent studies suggest the value of development and integration of new optical probes for detection and discrimination of cervical neoplasia using automated image analysis tools to reduce subjective variability and to provide remote areas with effective screening tools for early detection of cervical cancer. However, long-term studies using already available cervical images are needed to validate the potential of automated classification and recognition algorithms in discriminating cervical neoplasia and normal tissue. To facilitate such studies to be conducted and validated by multi-center investigators, effective dissemination of the image data over the Web from a central repository such as the National Library of Medicine is desirable. Currently, the National Library of Medicine (NLM) Communications Engineering Branch is collaborating with the National Cancer Institute (NCI) in a research and development project in the use of biomedical multimedia database technology for the study of human papillomavirus (HPV) in large-scale clinical data collections. In dissemination of such large databases, it is essential that image compression be used which has a high compression ratio yet which preserves crucial features of color and spatial detail, such as the degree of whiteness in acetowhite regions and fine vascular structures. Despite good performance of JPEG 2000 for most images, it does not have the flexibility to yield minimum distortion for specific classes of color images. Alternative methods using lossy compression and decompression are available to potentially increase the visual quality of the images considerably while simultaneously decreasing the file size. Source encoding in the wavelet domain is perhaps the leading method in this category. Wavelet-based encoding / decoding may be implemented in a variety of ways and the use of vector and scalar quantization methods within that domain are well known [5].

We have applied a recently developed, novel, wavelet-based hybrid encoding scheme [6-8], developed in the Computer Vision and Image Analysis Laboratory at Texas Tech University, to selected digitized cervical images to evaluate the performance of such a codec in retaining diagnostic features in cervical images. Our preliminary results suggest that such a codec could be used in designing a compact imaging system for screening cervical cancer as well as for disseminating cervical images to various study group from a central web based system (such as the WebMIRS [9]).

2. Methodology

Since the cervigram images were not taken by digital camera directly but rather saved as digital images by scanning from film, image quality was affected by possible film defects and poor scanning processes. Shot noise, film grain noise, blurring and scratches are generally introduced in the scanning process. Therefore, pre-processing of these noisy images before compression is essential to enhance the image quality. Figure 1 shows a schematic diagram of the processes which could be applied in recognition of cervical neoplasia or other abnormalities.

3. Hybrid multi-scale vector quantization (HMVQ)

When multi-scale vectors are used for codebook training using Euclidean distance as a distortion measure, distortions from each coefficient of the vector are equally weighed; thus, the

contribution to the distortion depends on the coefficients themselves instead of the order of the coefficients. This, in fact, codes the coefficients according to their magnitudes, rather than their order of occurrence, which is the principle used in EZW [10] and SPIHT [11]. Traditionally in vector quantization (VQ), vectors in the wavelet domain are generated by grouping neighboring wavelet coefficients within the same subband and orientation the same way as in the spatial domain. Vector dimensions vary and depend on the outcome of the adopted bit allocation scheme. Using multi-scale vectors makes it unnecessary to spend valuable bits in coding the locations of important coefficients, since the location information has been embedded in the vectors and in the order of the vectors.

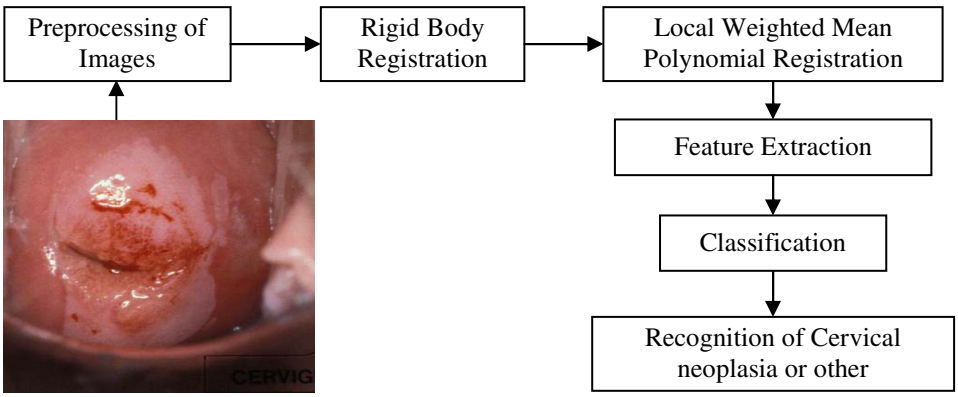


Figure 1. The entire process of digital image analysis for classification and recognition of a multi- or hyper-spectral image input is shown schematically.

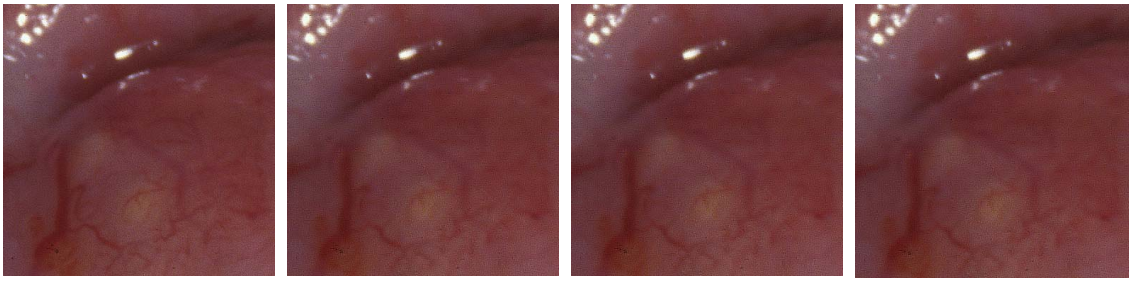
However, vector quantization normally produces a blurring effect in the images when they are encoded at low bit rates. When codebooks are generated by training a large number of samples via clustering algorithms, the codewords are the centroids of the partitions. When these centroids are used to represent all the vectors within the cells, some information is necessarily lost. If the vector space is not separated into sufficiently many partitions due to limitations in the codebook size, much detail information can be lost when such a codebook is used for image coding. The blurring effect due to information loss becomes more obvious at high compression ratios (low bit rates). In the wavelet domain, multi-resolution codebooks are often designed which increase the total codebook size (to include more detail) while keeping sub-codebooks small, thus maintaining a reasonable coding complexity [12]. The blurring effect comes essentially from the nature of codebook design methodology. It is necessary for a codebook to capture the major features of the representative training samples, but it is impossible to include every detail since the dimension of the codeword and the size of the codebook have to be reasonable for practical applications. It is therefore desirable to find another approach to make up for the lost details.

To accomplish this goal, we use a second-step residual coding, in which the differences between the original vectors and the nearest codewords are scalar quantized. The residual represents the detail information lost during vector quantization. When the codebook is well designed, the residual contains only a small number of large magnitude elements. In this case, only a few large magnitude elements have to be coded to compensate for the lost details, thus, bits can be saved. The advantage of combining multi-scale VQ with residual scalar quantization (SQ) is that the common features of a large variety of images can be represented in a codebook of reasonable size using vector quantization. The detail information of each image that deviates significantly from the common features can be specially coded using scalar quantization, thus

preserving the critical information and yielding a reconstructed image of better quality. We have extended our hybrid vector quantization codec (HMVQ) to color images by mapping RGB to YCbCr as in JPEG 2000. An optimized color mapping scheme is currently under investigation.

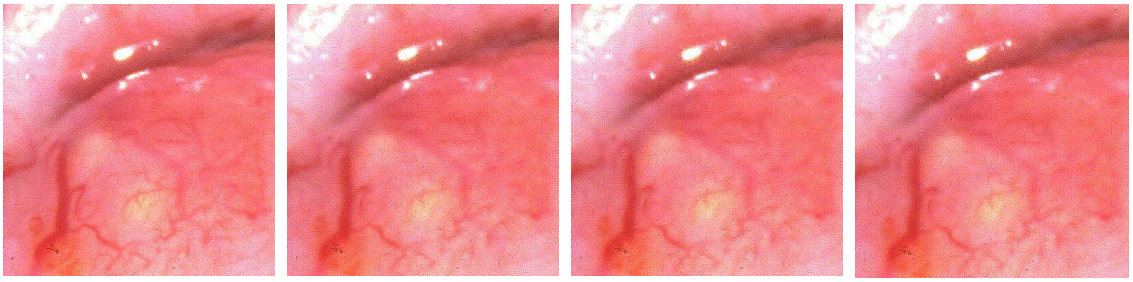
4. Results of multi-spectral HMVQ encoding

Figures 2 and 3 show the results of multi-spectral HMVQ encoding up to a compression ratio (CR) of 98:1. The visibility of the vasculature is perceived to be much better when simple contrast and brightness transformations are performed. Figure 4 shows how other diagnostic features are also retained up to a compression ratio of 96:1.



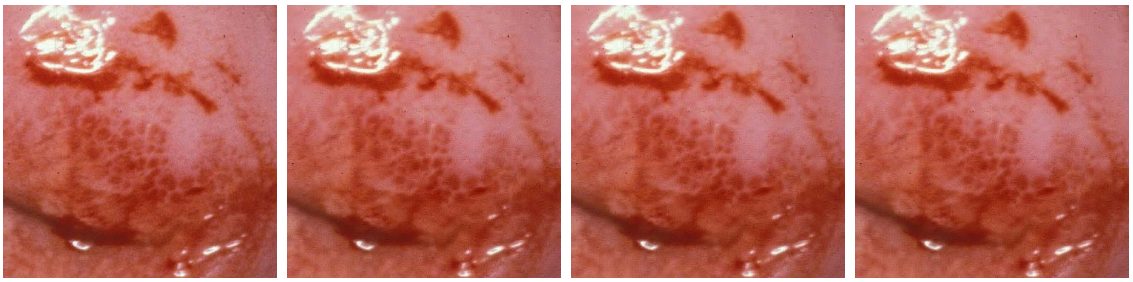
Original **CR: 62** **CR: 80** **CR: 98**

Figure 2. The vasculature in the above cervigram has been mostly retained by HMVQ compression for compression ratios ranging from 62:1 to 98:1.



Original **CR: 62** **CR: 80** **CR: 98**

Figure 3. A simple contrast and brightness change makes the poorly lighted cervigram in Figure 2 brighter for better visibility of the vasculature.



Original **CR: 60** **CR: 75** **CR: 96**

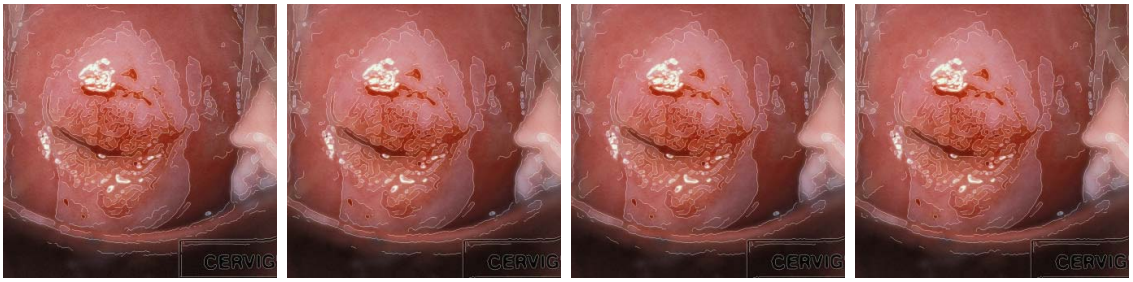
Figure 4. HMVQ compression using compression ratios ranging from 60 to 96 retains most of the diagnostic features in the above cervigram.

Proceedings of the 16th IEEE Symposium on Computer-Based Medical Systems (CBMS'03)
1063-7125/03 $17.00 © 2003 **IEEE**

Figures 5 and 6 show the effect of enhancing the cervical images to remove noise and enhance edges. In Figure 5, the image on the left is the original one, and the one on the right is the enhanced image. We sequentially used three types of filters to achieve the enhancement, namely Wiener, despeckle and unsharp mask. The Wiener filter is used to adaptively reduce the white noise across the whole image, which is probably introduced by poor quality scanning; a despeckle filter is to remove the speckles that are caused by film defects; and an unsharp mask is used to visually enhance the edges and thereby to produce a sharper image.

Original image **Enhanced version of the original image**

Figure 5. Effect of Image Enhancement



Original **CR: 60** **CR: 75** **CR: 96**

Figure 6. Edge detection applied on images at various levels of compression showing the contours of the acetowhite regions remaining unaffected by compression

The above examples of compression and enhancement of cervical images digitized from 35 mm cervigram slides demonstrate the potential of HMVQ compression in efficient dissemination of a large set of cervigrams (approximately 100,000) acquired by previous NCI studies for investigating the role of human papillomavirus (HPV) in the development of cervical cancer and its intraepithelial precursor lesions in women.

We are investigating the development of a system for computer-based recognition and classification of cervical neoplasia with the ultimate benefit of improving management and reducing healthcare cost for women with cervical neoplasia, a condition associated with high morbidity and mortality risk worldwide.

5. Conclusions and future work

The long term goal of the current research work is to design a multi-center integrated system for effective dissemination of the digitized cervigram image data over the Web from a central repository such as the NLM. The data will be readily available to national and international clinics and physicians for detection, localization, diagnosis and discrimination of the different severity levels of neoplasia, including normal mimics of neoplasia, in the pre-clinical and then

clinical setting. However, for effective dissemination of such large image databases, it is essential that image compression be used that has a high compression ratio yet preserves crucial features of color and spatial detail, such as the degree of whiteness and opacity in the acetowhite regions and fine vascular structures. Using the original uncompressed image as the criterion standard, the interpreter's responses to inspection of the corresponding compressed cervigrams will be compared. A baseline of inter-observer variability for inspection of the original cervigrams will be calculated. Using tests of agreement and Kappa statistics, inter-observer variability with inspection of the compressed images should remain at least 90% of that compared with the original cervigram. The one exception is clinical diagnosis in which comparable agreement is expected. These results will determine the maximum tolerable level of HMVQ compression allowed for archiving purposes. Such high fidelity compression will also be needed in designing compact imaging systems as screening tools for classification of cervical neoplasia.

References

[1] Campion MJ, Ferris DG, DiPaolo F, Reid R, Miller MD. Modern Colposcopy, A Practical Approach, ESI, Augusta, Georgia, 1991.

[2] Koss LG. The Papanicolaou test for cervical cancer detection. A triumph and tragedy. JAMA 1989; 261: 737-743.

[3] Richards-Kortum R, Mitchell MF, Ramanujam N, Mahadevan A, Thomsen S. In vivo fluorescence spectroscopy: Potential for non-invasive, automated diagnosis of cervical intraepithelial neoplasia and use as a surrogate endpoint biomarker. J Cellular Biochemistry 1994;19:111-9.

[4] Ferris DG, Lawhead RA, Dickman ED, Holtzapple N, Miller JA, Grogan S, et al. Multimodal Hyperspectral Imaging for the noninvasive diagnosis of Cervical Neoplasia. Journal of Lower Genital Tract Disease; 2001; 5:65-72.

[5] Barlaud, M.,Editor, Wavelets in Image Communication, Elsevier, 1994.

[6] Yang S and Mitra S, "Efficient storage and management of radiographic images using a novel wavelet based multiscale vector quantizer", SPIE Medical Imaging Symposium, San Diego, California, February 23-28, 2002.

[7] Yang S, Mitra S, Corona E, Nutter B, and Lee DJ, "Multi-level Wavelet Feature Statistics for Efficient Retrieval, Transmission, and Display of Medical Images by Hybrid Encoding", EUROSIP Journal on Applied Signal Processing, 2003,5,1-12.

[8] Yang S and Mitra S, "Content Based Vector Coder for Efficient Information Retrieval", Invited Book Chapter in **"**New Directions in Enhancing the power of the Internet", Editors: Nikravesh M, Azvine B, Yagar Y, and Zadeh LA. Physica-Verlag, Springer, March, 2003.

[9] X-ray image archive, National Library of Medicine, ftp://nlm.nih.gov.

[10] Shapiro JM, "Embedded image coding using zerotrees of wavelet coefficients," IEEE Transactions on Signal Processing, Vol.41, No.12, Dec, 1993.

[11] Said and Pearlman WA, "A new,fast and effcient image codec based on set partitioning in hierarchical trees," IEEE Transactions on Circuits and Systems for Video Technology, Vol. 6, No. 3, June,1996.

[12] Antonini M, Barlaud M, Mathieu P, and Daubechies I, "Image coding using wavelet transform," IEEE Trans. on Image Processing, vol. 1, No. 2, April 1992.